Appendix J4

Control Engineering Design Criteria

Control Engineering Design Criteria

1.0 Introduction

This section covers the design criteria which will be used for all control work related to this project. Variations from the design criteria are expected to support unique design applications or to accept manufacturers' standard equipment packages. The lead control engineer will authorize all variations in design criteria.

2.0 Design Codes and Standards

The design specification of all work will be in accordance with the applicable laws and regulations of the federal government and the State of California, and applicable local codes and ordinances. The federal and state codes and standards requiring compliance under penalty of law are outlined in the Regulatory Requirements Manual. A summary of codes and industry standards applicable to design and construction follows:

- American National Standards Institute (ANSI).
- American Society of Mechanical Engineers (ASME).
- The Institute of Electrical and Electronics Engineers (IEEE).
- Instrument Society of America (ISA).
- National Electrical Manufacturers Association (NEMA).
- National Electrical Safety Code (NESC).
- National Fire Protection Association (NFPA).
- Scientific Apparatus Makers Association (SAMA).

Other recognized standards will be utilized as required to serve as design, fabrication, and construction guidelines when not in conflict with the above listed standards.

The codes and industry standards used for design, fabrication, and construction will be the codes and industry standards, including all addenda, in effect as stated in equipment and construction purchase or contract documents.

3.0 General Requirements

3.1 Ambient Conditions

All instruments and control devices will be designed to withstand ambient conditions appropriate to their mounting location or be suitably protected.

The evaluated operating conditions for instruments and control devices installed in heated/air-conditioned areas will include air conditioning failure.

3.2 Power Supplies

All instruments and control devices will be designed to operate on power supplies as follows:

- Electric:
  - 120 volt ac, 60 hertz, single-phase for motor control center (MCC), solenoid valve, and low torque drives with guaranteed satisfactory operation when equipment is continuously energized at any voltage from 100 to 132 volts ac.
  - 125 volt dc for control (switchgear) and low torque drives.
  - 120 volt ac, 60 hertz, for control logic (digital input interrogation voltage).
  - 480 volt ac, 60 hertz, three-phase for high torque drives.

  Any voltage required other than the above will be furnished by the equipment supplier.
- Pneumatic--Clean, dry, and oil free instrument air at 70 to 125 psig. All necessary pressure reducing controls (pressure regulators), where required, will be furnished by the equipment supplier.

3.3 Standard Ranges of Analog Signals

The ranges of analog signals will normally be as follows:

- Electric--4 to 20 mA dc.
- Pneumatic--3 to 15 psig.
- Thermocouple--Type K.
- RTD--100 ohm platinum.

The use of any signal range other than the above will be avoided.

3.4 Contact Ratings

The ratings of all instrument contacts used for alarm and interlocking will be coordinated to meet the requirements of the interfacing/interlocking system. The ratings of all solid-state control system output contacts will be coordinated to meet the requirements of the driven device/equipment. Consideration will be given to the voltage and current rating, continuous rating, maximum rating (break), and switch rating (break).

4.0 Instruments

Instrument housings will be in accordance with the NEMA, or other project designated authority rating for the area in which the instrument is located.

4.1 Instrument Primary Piping (Impulse Lines)

Instrument primary piping/tubing is defined as the piping or tubing directly connected to the process, beginning at the outlet of the root valve and terminating at the blowdown valve, and at the point of connection to the instrument itself.

4.1.1 Instrument Primary Piping/Tubing

The preferred material for installation of instrument primary tubing is stainless steel tubing using grip type fittings. Socket weld fittings will be used on tubing having 0.083 inch or greater wall thickness. Changes in instrument primary tubing direction will utilize tube fittings, or for 0.065 or less wall thickness, tubing may be bent.

4.1.1.1 Design Pressure and Temperature. Instrument primary tubing design pressure and temperature will be selected consistent with the requirements discussed in Section 11.0 of this manual for the process pipe to which the instrument primary tubing is connected.

4.1.1.2 Sizes of Instrument Primary Tubing. Instrument primary tubing size will be as follows:

- Pressure measurement tubing will be 0.500 inch outside diameter with minimum wall sizes of 0.049 inch or 0.065 inch, depending on the pressure and temperature of the process.
- Flow and level measurement by differential pressure will also use primary tubing conforming to the above requirements.
- When instrument manifolds are furnished, 0.25 inch outside diameter stainless steel flexible metal hoses may be used as a flex line (less than 18 inch length) between the instrument manifold and the instrument. Direct manifold mounting of the instrument to the manifold is preferred.

4.1.1.3 Materials for Instrument Primary Tubing. Only one material for instrument primary tubing is recommended:

- ASTM A269, GR TP316 seamless tubing.

Other types of stainless steel materials may be required by design due to environmental considerations or client preference.

4.1.1.4 Support of Instrument Tubing. Instrument primary tubing will be supported in accordance with ANSI B31.1. In general, 0.500 inch OD stainless steel tubing will be supported continuously. The support system will allow for thermal expansion of tubing and equipment.

4.1.2 Instrument Primary Piping/Pipe

Pipe will be used for instrument primary piping only when physically required to support the instrument and will normally be all socket welded.

4.1.2.1 Design Pressure and Temperature. Instrument primary piping design pressure and temperature will be selected consistent with the requirements discussed in Section 11.0 of this manual for the process pipe to which the instrument primary piping is connected. The following criteria will also apply:

- Instrument primary piping for steam systems will be designed for the maximum sustained process pressure (plus 25 psi) and the maximum sustained process system temperature (plus 10° F).
- Instrument primary piping for other than steam systems will be designed for the maximum sustained process system pressure (plus 25 psi) and the maximum sustained process system temperature (plus 10° F).

4.1.2.2 Sizes of Instrument Primary Pipe. Instrument primary piping will not be smaller than the connection at the process pipe root valve and/or the following:

- 1/2 inch for pressure measurement piping with a design pressure equal to or less than 600 psig and a design temperature equal to or less than 750° F.
- 3/4 inch for pressure measurement piping with a design pressure greater than 600 psig or a design temperature greater than 750° F.
- Flow and level measurement by differential pressure will also use primary piping conforming to the above requirements; however, flange tap connections for flow measurements may be of 1/2 inch size.
- Float actuated level switch devices will be supported on connecting piping not smaller than 1 inch.
- Level controllers and transmitters of the displacement float type will be supported on connecting piping not smaller than 2 inches.
- Instrument columns for float actuated level switches and displacement float devices will normally be piping of not less than 2-1/2 inches.
- Primary piping internal diameter shall not be less than 0.30 inch between the process connection and instrument blowdown valve.

4.1.2.3 Materials for Instrument Primary Pipe. Material for instrument primary piping connecting to the root valve will preferably be the same as that used between the system process header and the root valve. Higher strength materials may be substituted in the interest of standardization; however, welding procedures at the point of joining the instrument primary piping to the root valve must be appropriate to the combination of materials involved. Copper or brass may be used only for water services that use copper, brass, or nonmetallic process piping.

4.1.2.4 Support of Instrument Pipe. Instrument primary piping will be supported consistent with the requirements discussed in Section 11.0 of this manual. Preinsulated, heat traced, tubing bundles may also be used.

4.1.3 Insulation of Instrument Primary Piping/Tubing

Instrument primary piping/tubing connecting to high temperature systems, which might become hot enough to injure personnel during blowdown of the instrument line, will be insulated where such hazard exists. Insulation materials, exterior finish, and metal lagging will conform to the standards adopted for the process piping as discussed in Section 11.5 of this manual.

4.1.4 Criteria for Routing Instrument Primary Piping/Tubing

Routing of instrument primary piping/tubing, including piping from the process connection through the root valve and the instrument primary piping/tubing, will be in accordance with the following criteria.

Special fittings such as reservoirs and other devices shall be installed at differential pressure connections as required by the process parameter to be measured and the design of the instrument.

Pressure sensed by the instrument will differ from pressure in the process if there is a head of liquid in the instrument line. This effect may be significant if the instrument line static head is large in comparison with the pressure being sensed. This effect can be accounted for in calibration of the instrument if the static head is constant. To assure a constant static head, the connections from low-pressure steam and low-pressure liquid filled lines should preferably slope downward continuously from the primary element connection to the instrument. Horizontal runs should have a slope of not less than 1/2 inch per foot and must be adequately supported to maintain a constant slope. If downward slope is not feasible, the line should slope upward continuously and a loop seal (steam service only) should be installed at the instrument to assure a water seal for temperature protection. Upward sloping liquid lines should be used only if the process pressure is sufficient to assure a head of liquid at the instrument. Provision for venting of air should be provided in the high point of the line, preferably at the instrument. Upward sloping steam lines should not be less than 1 inch in size. Vacuum connections should always slope upward to the instrument.

Instrument primary piping/tubing for steam flow, liquid flow, and manometer level measurement systems should preferably slope downward from the primary element connections to the instrument. Instrument primary piping/tubing for fuel gas, compressed air, flue gas, and airflow measurement systems should preferably slope upward from the primary element connections to the instrument. If these requirements cannot be met, special venting or drain provisions will be required.

Pressure taps will be located on the top or side of gas, or air piping, and on the top (if pressure is high enough to vent any air in the instrument line) or side of liquid filled or steam piping. Pressure taps on boiler gas and air ducts will be located on the top or side to permit draining condensation.

4.1.5 Support of Instrument Piping

Instrument primary piping will be supported at intervals not exceeding 6 feet. Usage of seamless stainless steel tubing and its installation as an alternative to pipe must be in accordance with ASME B31.1 or other codes and standards referenced in Section 11.2 of this manual as applicable. Intermittently supported tubing must be the same or larger OD than the nominal pipe size it replaces. Usage of smaller OD tubing dictates continuous support to assure maintaining proper slope.

4.2 Thermowells and Protecting Tubes

The selection, construction, and location of thermowells will be in accordance with the recommendations and standards set forth in the following references:

- ASME PTC19.3--Temperature Measurement.
- ASME B31.1--Code for Pressure Piping.
- ASME Boiler and Pressure Vessel Code, Section VIII, Division 1.

Thermowells will be selected to provide the insertion lengths recommended in the ASME Performance Test Codes appropriate to the process being monitored. For applications not covered by PTC recommendations, the tip of the thermowell should normally extend into flowing pipelines not less than 3 inches. The maximum insertion length should be chosen such that the tip does not extend beyond the pipe center line.

Two methods are generally used to install thermowells in pipe:

- Perpendicular to the pipe.
- Parallel to the pipe in an elbow or tee.

Thermowells will generally be installed into welded forged steel screw end adapters, such as Bonney Forge “Threadolets” and “Elbolets,” or equivalent. Pipe couplings will not be used.

Fluid system temperature sensors will be equipped with thermowells and will be made of one piece, solid bored Type 316 stainless steel of stepless tapered design in accordance with

ASME PTC 19.3. The sizes of the connections will be as defined in Section 11.0. Threaded temperature wells in lines operating above 600 psi will be seal welded after installation. Normal bore diameter will be sized to accommodate 0.25 inch sheaths. Maximum bore internal diameter will be 0.387 inch.

Thermowells in main steam and feedwater piping will be designed to prevent damage caused by vortex-induced vibration over the range of velocities encountered in normal service in accordance with ASME Performance Test Code 19.3, Temperature Measurements.

All thermowells in steam piping will be permanently installed and welded after steam blow to avoid exposure to vibration damage. For steam blow, the connections will be plugged by screwed plugs after assuring thermowells can be properly inserted. All other thermowells will be installed prior to hydrostatic testing.

Test wells will be provided on main steam, feedwater, and other piping as required to meet ASME or other project designated test requirements.

Temperature detectors in boiler gas and air ducts will be mounted in protecting tubes to provide mechanical support and to permit replacement while in operation. Protecting tubes will be made of Type 316 stainless steel pipe not smaller than 1/2 inch size, with screwed pipe bushings welded to the tubes for attachment to the ducts. Duct connections will consist of screwed couplings or adapter flanges welded to the ducts, into which the bushings on the protecting tubes can be threaded. Duct connections will be located to minimize the effect of temperature stratification within the ducts. Protecting tubes exceeding 3 feet in length shall be provided with additional supports within the boiler casing or duct.

4.3 Thermocouples and Resistance Temperature Detectors

Project temperature measurements for remote use will be by temperature detectors.

Temperature detectors will preferably be thermocouples. Thermocouples will be of the chromel-alumel type (ISA Type K) with Type KX extension wire. Thermocouples and extension wire will comply with the standard limits of error in accordance with ANSI MC96.1-1975. The elements as a rule will be separate from ground (ungrounded).

Resistance temperature detectors (RTDs) will be of the 3 wire platinum type. The nominal resistance of the platinum detectors will be 100 ohms at 0° C. All RTDs for measurement of fluid system temperature will be ungrounded, metal sheathed, ceramic packed, and suitable for the design temperature, pressure, and velocity of the fluid system.

Thermocouples and RTDs will have sheathed elements spring-loaded to provide good thermal contact with the well or protecting tube. The sheath will be made of stainless steel having swaged type magnesium oxide insulation. All connection heads will be weatherproof, made of cast iron with screwed covers, and supported from the well by a stainless steel extension nipple.

4.4 Transmitters

Transmitters will generally be used to provide the required signals (4 to 20 mA dc) for control and monitoring by operators in remote control center areas. Where possible, transmitters will be of the electronic 2 wire type, capable of driving a load up to 750 ohms, designed with provisions for zero and span adjustments, and will have 0.25 percent accuracy.

4.4.1 Static Pressure and Differential Pressure Transmitters

Sensing elements for static pressure and differential pressure transmitters will be of the capacitance type.

For steam and water services, static pressure transmitters will be equipped with a two-valve manifold, and differential pressure transmitters will be equipped with a three-valve manifold. Manifolds will be constructed in accordance with ASME B31.1.

4.4.2 Level Transmitters

Sensing elements for level transmitters will be of the following types:

- Static head devices for vessels exposed to atmospheric pressure; air bubbler type devices may be used if absorption of air by the liquid is not objectionable. (Level transmitters of this type are the same as static pressure transmitters.)
- Displacement float type for feedwater heaters and enclosed vessels (where practical).
- Differential pressure type with constant head chamber for high-pressure and temperature applications where installation of float cage becomes impractical. (Level transmitters of this type are the same as differential pressure transmitters.) Tank level installations will include flanged isolation valves.
- Moving float type for fuel oil storage tanks.
- Admittance probe type or ultrasonic type for specialized applications.

4.4.3 Flow Transmitters

Flow transmitters for general applications will be of the differential pressure type:

- Primary Elements--Flow nozzles will be used for feedwater flow, steam flow, and other critical measurements where weld-in construction is required. Flow nozzles will be made of stainless steel with dual sets of pressure taps installed in the pipe wall where required. Installation of flow nozzles and pressure taps will be made in the flow nozzle manufacturer's shop or in the pipe fabricator's shop. Feedwater flow and steam flow nozzles will be calibrated.

Paddle type orifice plates will be used for other flow measurements where flanged construction and higher pressure loss are acceptable. Orifice plates will be made of stainless steel. Orifice flanges will be of the raised face weld neck type with dual sets of taps unless design dictates otherwise.

Construction and installation of flow nozzles and orifices will conform to the requirements of ASME Performance Test Code PTC 19.5, and discharge coefficients will be predicted in accordance with data published in ASME Research Report on Fluid Meters.

Airfoil or venturi flow sections, or averaging type pitot tubes, may be used for measuring boiler combustion airflow.

Annubars, piezometers, and pitot tubes will be used for measuring flows in large pipes or ducts where installation of flow nozzles, orifice plates, or airfoils is impractical.

- Secondary Elements--Secondary elements for differential type flow sensors will be capacitance type differential pressure transmitters.
- Positive displacement type flowmeters will be used for measuring fuel oil flows.
- Turbine flowmeters or orifice type flow sections will be used for measuring gas flows.

4.5 Process Measurement Switches

Process measurement switches will generally have double-pole, double-throw or two single-pole, double-throw (two Form C) contacts (if deadband is not a factor) for each actuation point, and will be equipped with screw type or compression type terminal connections on a terminal block for terminating field wiring. Switches for use with programmable control systems may utilize SPDT construction. Switch set point will be adjustable. Contacts will be of the snap-acting type.

4.5.1 Temperature Switches

Temperature switches will be actuated by filled-bulb type elements equipped with standard length armored capillary tubing.

4.5.2 Pressure Switches

Pressure switches will be actuated by diaphragm type elements. Pressure switches will be classified into the following types:

- General static pressure switches and general differential pressure switches for normal static pressure ranges.
- Low differential pressure switches for low static pressure ranges.
- Low differential pressure switches for high static pressure and/or applications requiring both indication and pressure switch contacts.

4.5.3 Level Switches

Level switches will be actuated by elements of the following types:

- Static head devices for vessels exposed to atmospheric pressure; air bubbler type devices may be used if absorption of air by the liquid is not objectionable. (Level switches of this type are the same as static pressure switches.)
- Differential type for high-pressure and high temperature applications. (Level switches of this type are the same as differential pressure switches.)
- Moving float type for enclosed vessels and sumps.
- Displacement float type for open tanks and sumps.
- Capacitance, RF/admittance, or ultrasonic type for specialized applications.

Switching elements of moving float and displacement float type level switches will have float and body construction appropriate to the service conditions of the systems to which they are connected. Switch elements shall be of the vibration resistant, snap-acting type magnetically coupled to the float. Two switch elements or one DPDT switch element will be available at each level point monitored.

Each switch element will be reversible for NC or NO operation, or will be double-throw construction. Switch element leads will be of high temperature construction as required, and terminated on terminal blocks within the switch housing. Switch housings will be NEMA 4 construction, unless otherwise specified.

4.5.4 Flow Switches

Variable area or differential pressure type actuating elements will be used for low flow and low-pressure applications.

4.6 Local Indicators

4.6.1 Local Temperature Indicators (Thermometers)

Thermometers for local mounting will be 4-1/2 inch dial, bi-metal. Thermometers for panel mounting will be gas-actuated with stainless steel armored capillary tubing of the length required for installation with 4-1/2 inch minimum dial size. Dial scales shall be such that the normal operating range is in the middle third of the dial range. The dials will be engraved with service legends, or separate nameplates will be furnished to identify the service. Separate nameplates shall be engraved phenolic attached to the dial face or stamped stainless steel attached to the thermometer by stainless steel wire. Thermowells or protection tubes (for boiler gas and air ducts) will be furnished for all thermometers.

4.6.2 Local Pressure Indicators (Pressure Gauges)

Gauges for control air supply and signal pressures integral to an instrument will be in accordance with the instrument manufacturer's standards. All other gauges shall be 4-1/2 inch minimum dial size. Dial scales shall be such that the normal operating range is in the middle third of the dial range. Separate nameplates shall be engraved phenolic attached to the dial face or stamped stainless steel attached to the gauge by stainless steel wire. All gauges will have stainless steel movements. Gauges for panel mounting shall be of the flush mounting type. Gauges for separate mountings shall have 1/2 inch NPT bottom connections. Gauges that are expected to pulse more than ±5 percent of scale shall be furnished with a pulsation dampener made of the same material as the Bourdon tube or stainless steel. Gauges used in compressed gas applications or those equipped with diaphragm seals will not be furnished with pulsation dampeners. Gauges for fluids which may be corrosive to the gauge internals will be furnished with glycerine filled cases and diaphragm seals. Gauges required by a specific code (NFPA 20) will be supplied in accordance with the code.

4.7 Solenoid Valves

Solenoid coils will be Class H high temperature construction and will be designed for continuous duty. Three-way solenoid valves will be designed for universal operation so that the air supply may be connected to any port.

5.0 Control and Information Systems

5.1 General Design Criteria

The objective of the control and information systems is to facilitate plant operations by ensuring personnel safety, equipment protection, adequate operation, and plant availability. The control and information systems will ensure these criteria are met by incorporating the following design features:

- Centralized control location(s).
- Reasonably consistent operator interface.
- Redundancy of key critical components.
- Fail-safe design of protective systems.
- Cost-effective design.

The principal functions provided by the control and information systems are listed below and discussed in the following sections:

- Discrete control
- Protection
- Information
- Annunciation

These functions will be provided by systems which utilize programmable microprocessor based hardware. System control strategies will be implemented using software programmable, digital computing techniques.

All combustion turbine controls and monitoring will be performed in the GE furnished control system. The balance-of-plant modulating controls and process monitoring will also be performed in the GE furnished control system.

The primary operator interface to the balance-of-plant modulating controls, the combustion turbine generator, and the balance-of-plant motor controls will be through the GE operator interface.

5.2 Discrete Control

Discrete control logic will be provided for motors (pumps, fans, compressors, and similar equipment), motor and solenoid operated valves, and auxiliary electric breakers. Discrete control logic will also be provided to coordinate the actions of a group of equipment. The logic may be as simple as operating two motor-operated valves in tandem, or as complex as automatic startup logic for slaved auxiliaries for fan control.

5.2.1 Equipment Control

The logic provided for individual pieces of plant equipment will be designed to minimize the requirement for operator interface. The logic will be designed to incorporate permissives which ensure that the prerequisite conditions for safe operation are met prior to allowing the equipment to start, open, or close, as appropriate. Similarly, the logic will incorporate interlocks to prevent equipment from operating in an unsafe or potentially damaging condition.

Equipment control will generally be classified into three modes: manual (operator control), automatic, and standby.

In the manual mode, the operator is required to start and stop or open and close the equipment in response to plant operating needs. Equipment that is not frequently operated, such as auxiliary electric system feeder breakers, or equipment which is normally not started without supervision will only be provided with the manual control mode.

The automatic control mode will be provided for equipment which must start and stop frequently to maintain process control. An example of automatic control logic is a tank fill pump which is automatically started at a low tank level and stopped at a high tank level. As a general rule, actions initiated by automatic logic will not be annunciated. Failure of an automatic action to occur will be annunciated if initiated by a protective interlock.

The standby control mode will be provided for redundant equipment, or equipment which has a designated backup. Examples of equipment which will be capable of standby operation are redundant closed cycle cooling water pumps (2 times 100 percent or 3 times 50 percent) and turbine lube oil pumps. If equipment is in the standby mode, it will be started automatically when the operating equipment trips or a process parameter indicates that the operating equipment has failed. Following a standby start, the equipment will continue to operate until stopped by the operator, or until tripped by a protective interlock. An alarm will be provided to alert the operator that the equipment has standby started.

All equipment will be provided with the manual control mode. Automatic and standby control modes will be provided for equipment as appropriate.

5.3 Protection

Protection logic will be implemented at two levels. Individual equipment will be protected by logic contained within the processors or control system implementing the equipment control logic.

Individual equipment will be protected against conditions such as abnormal temperature, pressure, level, and/or flow as appropriate. This protection will be incorporated into the discrete control logic provided for the equipment and will exist in the form of permissives and interlocks. Proprietary control systems provided with equipment such as the turbine generators contain the protective logic necessary to guard against conditions such as high vibration, abnormal oil temperature, low oil pressure, overspeed, and other potentially dangerous or damaging conditions.

A system of hard-wired protective and lockout relays will be provided to protect the generators and transformers. These devices are discussed in Section 12.0 of this Appendix H.

5.4 Information

The control systems will provide real-time information to the operators in several formats as follows:

- Process graphic displays--The process graphic displays present information to the operator in formats similar to simplified Piping and Instrument Diagrams or equipment pictorials. Process information and equipment status are presented as dynamic text values and symbol colors. Operator control actions may be affected through the process graphic displays.
- Faceplate displays--Faceplate displays consist of an intelligent grouping of manual/auto stations or control "faceplates" associated with a given piece of equipment or process. Operator control actions will be affected through the face-plate displays.
- Bar chart displays--Bar chart displays consist of a grouping of vertical or horizontal dynamic bar graphs associated with a particular process. Bar charts provide an analog representation of process parameters for quick operator recognition and comparison.

- Trend displays--Trend displays provide a dynamic graphical representation of analog (or discrete) values versus time. Trend displays replace the function of ink type "strip chart" recorders. Trend displays provide the capability to scroll backwards in time to review performance or process trends, thereby assisting in troubleshooting and post-trip analysis.

5.5 Annunciation

The control systems will annunciate the occurrence of abnormal events in the form of CRT alarm summaries, printed alarm logs, and audible tones.

The operators will be alerted to the occurrence of abnormal events and the return of abnormal events to normal operating conditions. The conditions to be annunciated include those that are potentially dangerous to personnel or damaging to equipment, those that may affect the plant's load carrying capability, and those indicative of processes or equipment that are operating in an abnormal or inefficient condition. Return-to-normal operating conditions will not be annunciated.

The alarm printer will provide a hard copy printout of the alarm conditions that appear on the operator work stations.

5.6 Control Hardware

The combustion turbine control hardware and balance-of-plant control hardware for this Project will be supplied by GE.

5.7 Location of Control Equipment

Control equipment refers to the equipment and devices necessary to implement the modulating and discrete control strategies, and the equipment provided for operator interface with the control systems.

Control equipment will be located according to the following criteria:

- Pneumatic controllers will be field mounted in close proximity to the controlled process.
- Control devices such as switches and transmitters will be located on local instrument support structures.
- Control system input and output devices (I/O) will be located in environments compatible with the hardware. I/O hardware will be physically distributed where practical to reduce cable costs.

- Equipment provided for the primary operator interface will be located in the main control room. Local control areas may be established in conjunction with packaged equipment or as necessary to meet specific project requirements.

5.7.1 Local Control Areas

Local control areas will be established for systems where it is advantageous to have control hardware or provisions for operator control in the vicinity of the equipment being controlled. Operator interface stations will be located in the control modules.

Each of these areas will be provided with sufficient local control devices for an operator to initiate a startup or shutdown of the controlled equipment with provisions for operator manual control of the process.

6.0 Final Control Devices

6.1 General Design Criteria

Final control devices will be supplied with the necessary signal conditioning and sensing devices to adequately interface with the control system.

6.2 Modulating Valves and Drives

6.2.1 Control Valves

Air-operated modulating valves controlled from an electronic control system will be provided with a valve positioner capable of receiving a 4 to 20 mA signal and converting the signal to an air pressure signal corresponding to the force required to move the valve diaphragm to the adjusted position. In certain instances when an electronic-to-pneumatic positioner is not commercially available, a combination of an signal converter (electropneumatic) and pneumatic valve positioner will be supplied.

6.2.2 Control Drives

Control drives modulating boiler process dampers and other process related equipment will be capable of receiving a 4 to 20 mA signal. The drive will include integral position switches and/or a position transmitter. The drives and associated linkages will be sized to accommodate the maximum operating force required by the damper or driven equipment. Drive operating speeds will accommodate the process dynamics of the system.

6.3 Open/Close Valves and Operators

6.3.1 Air-Operated Valves and Operators

Air-operated open/close valves and operators controlled from the electronic control system will include solenoid valves and open/close position switches. Failure mode will be determined during detailed design.

6.3.2 Electrically Operated Valves and Operators

Electrically operated open/close/jog valves and operators controlled from the electronic control system will include integral position switches. Valves and operators required to jog (stop in an undetermined, intermediated position) will include position transmitters.

7.0 Operator Interface

Operator interface devices will be designed in accordance with ISA Recommended Practice 60.3 and, in particular, the following human factors design criteria:

- Safety--Consideration will be given to safety, including minimization of potential human error in the operation or maintenance of plant equipment using the DCS control equipment.
- Standardization--Controls, displays, nomenclature, color selection, and arrangement schemes will be consistent for common functions of all equipment.
- Allocation of Functions--The allocation of control functions between man and machine will be optimized based on study or prior successful experience.
- Ergonomics--The physical design and construction of equipment will give consideration to human engineering ergonomics.
- Interaction--The operator will have all control devices and displays necessary to fulfill his assignment at his disposal and within his reach and visual range.

In consideration of the above criteria, provisions will be made for remote (control room) operator interaction with plant systems and equipment, which are routinely started and stopped, adjusted, or require hourly monitoring.